Error Mapping and Automated Calibration of PrISMM

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LLNL can and should be the premier facility for hydrodynamic material fabrication and precision manufacturing/metrology of defense-related components, such as machining, part metrology, pin-dome assembly, and hydro assembly. Significant investments from various LLNL program sources have already been made. The future success of LLNL requires it to stand out above the other sites. The Precision Inspection Spherical Measuring Machine (PrISMM), shown in Fig. 1, will replace the current instrument used for part metrology, shown in Fig. 2, which is not only 40 years old, but is showing reproducibility error that is worse than tolerances needed for future defense-related work.

In this project, we will prepare PrISMM to be the primary shell-measuring machine at LLNL and potentially serve as a model for the entire nuclear weapons complex. This involves increasing its current accuracy through a modeling and compensation methodology, and automating measurement and mastering algorithms for operation by inspectors within LLNL's inspection shop. In its current state, PrISMM is degraded in accuracy due to incomplete error mapping and compensation. Also, the complexity of setting up and operating PrISMM precludes its use as a shop tool by members of the inspection shop. An important goal is to transition its operating procedure and control software for convenient use by shop personnel.

Project Goals

The goal is to produce a reliable and accurate shell-measuring tool for use by the inspection shop. A software compensation capability will be demonstrated as well as automated routines for probe

Figure 1. Precision Inspection Spherical Measuring Machine (PrISMM).

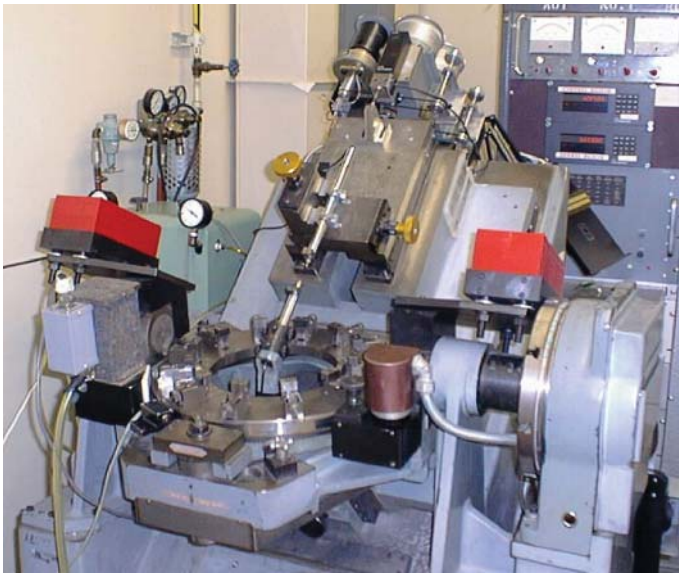

Figure 2. Rotary Contour Gage, the current spherical measuring machine.

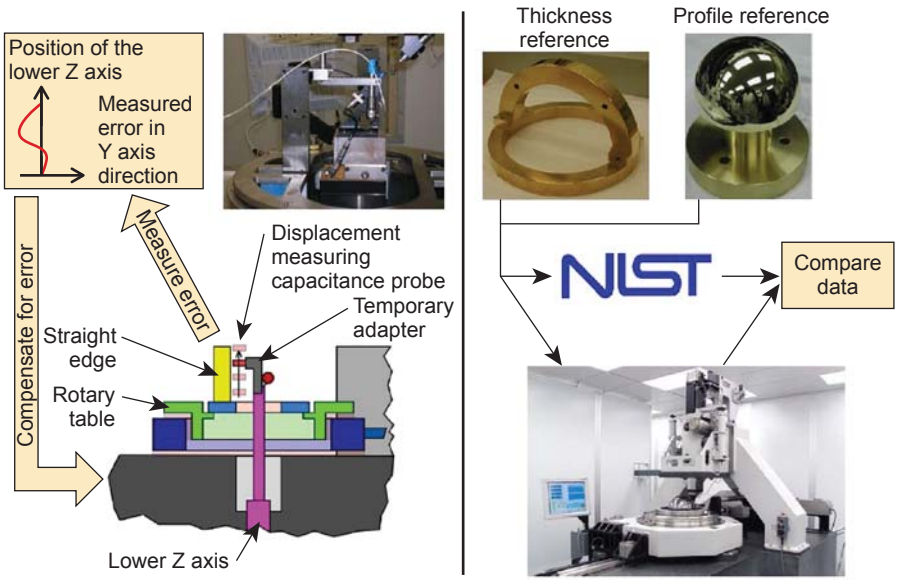

Figure 3. Software error compensation and validation using calibrated reference parts on PrISMM.

calibration. The final goal of this project is to transition the operation of PrISMM to the inspection shop staff. In this effort, a precision engineer will improve the accuracy and usability of PrISMM.

Relevance to LLNL Mission

The shell-measuring capability is a critical capability for support of defense-related work both at the Laboratory and nationally. This project aligns with LLNL's Measurement Technology focus area.

FY2008 Accomplishments and Results

Through a series of recent upgrades, including an upgrade of the laser position feedback system, PrISMM is now a reliable measuring machine. We did not have down time due to problems with the machine throughout FY2008. Figure 3 shows the error compensation methodology as well as methods for validation of this compensation. A procedure and software have been created for measurement and generation of compensation tables for the positioning, straightness, and squareness errors of the four axes. These procedures and software have been demonstrated and have shown that individual errors can be compensated down to the repeatability of the machine. PrISMM has successfully measured a standard spherical part, which was measured at the National Institute of Standards and Technology (NIST), to an accuracy of 1 µm.

Automated mastering routines have been created which will decrease the complexity and increase repeatability of machine setup. PrISMM mastering involves geometrically relating the upper Z probe to the lower Z probe. The calibrated test fixture, shown in Fig. 4, contains a precision sphere used for the mastering routine. The calibrated test sphere allows the determination of the spatial relation between the upper and lower probes, and facilitates measurements of probe radii and profile. An automated routine for finding the pole of the test sphere has been created and tested.

Related References

1. Blaedel, K. L., "Error Reduction in Technology of Machine Tools," *Technology of Machine Tools – Machine Tool Accuracy*, pp. 61–71, 1980.
2. PMAC Users Manual, Delta Tau Data Systems, Inc., Northridge, California.

Project Summary

An error compensation methodology has been created that can compensate axis errors to the repeatability of the machine. This process has been demonstrated and a standard part has been measured to an accuracy of 1 µm. Automated mastering routines have been created and have been partially implemented to decrease the complexity of machine setup. PrISMM is now a reliable and accurate metrology instrument for the measurement shells for current and future defense-related work.

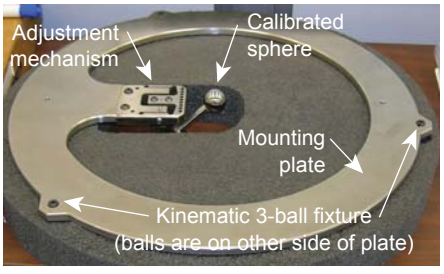

Figure 4. Master ball fixture used to calibrate the two measurement probes on PrISMM.